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IMPACTS OF CLIMATE CHANGE

Influences of Urban Temperature on the Electricity Consumption of Shanghai

HOU Yi-Ling[1,2], MU Hai-Zhen[2], DONG Guang-Tao[2], SHI Jun[2]

[1] *Nanjing University of Information Science & Technology, Nanjing* 210044, *China*
[2] *Shanghai Climate Centre, Shanghai Meteorological Bureau, Shanghai* 200030, *China*

Abstract

By using data of daily electricity consumption and temperature for the period 2003–2007 in Shanghai, the variation of energy consumption and the correlations between energy consumption and temperature are analyzed. The results indicate that winter and summer are the two peak seasons of energy consumption due to the urban residential heating and cooling demand. The base temperature of electricity and daily temperature is 10°C in winter and 22°C in summer respectively. When the outdoor temperature is below 10°C, the heating demand becomes obvious, and with over 22°C the cooling demand. The spatial distribution of cooling degree-days (CDD) and heating degree-days (HDD) clearly shows urbanization effects. By the influence of urbanization the central city experiences greater CDD in summer and lower HDD in winter. The projected temperature for 2011–2050 implies a significant increase in CDD and a decrease in HDD. This may have implications on the future energy demand if the current energy consumption pattern does not change.

Keywords: electricity consumption; temperature; heating and cooling period; Shanghai

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1 Introduction

It is generally agreed that climate is one of the key factors influencing the energy consumption (Colombo et al., 1999; Hekkenberg et al., 2009). Amongst various climatic factors, which may affect the energy consumption, temperature is the most dominant one (Yan, 1998). Cline (1992) provided the earliest study on the impacts of climate change in his seminal book The Economics of Global Warming. Akbari et al. (1992) reported that the peak cooling electricity load in some U.S. cities would increase by 0.5% to 3% with an ambient temperature increase of 0.6°C. Deschênes and Greenstone (2007) provided the first panel-data based approach for estimating the impacts of climate change on residential electricity demand. Their estimates suggest an increase in residential energy consumption in the range of 30%–35% based on the Hadley 3 A1FI predictions, and about 15% with the CCSM A2 predictions. Chen et al. (2006) reported that the winter heating energy consumption reduced by 5% to 30% in northern China and by more than 30% in the Yangtze delta from 1985 to 2004 due to global warming. The IPCC Fifth Assessment Report (IPCC, 2013) assessed that the globally averaged combined land and sea surface temperature as calculated by a linear trend, shows a warming of 0.85 (0.65–1.06)°C. Shanghai, with the influences of the heat island effect and global warming, shows an annual mean temperature of 16.9°C for the period of 1981–2010,

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Corresponding author: HOU Yi-Ling, houyiling2001@hotmail.com

with the highest temperature of 40.0°C in the 2010 summer and the lowest temperature of –8.0°C in the 1991 winter.

With the economic development and the improvement of living standards, an increase in electricity consumption is needed. Data from CEIC (CEIC Data Co., Ltd) indicate that the number of air conditioners in Shanghai has increased dramatically in the period 2001–2010. The number of air conditioners per 100 households was 200 in urban and 147 in rural area in 2010, respectively, while the electricity consumption was 134×10^9 kW h in 2011 (SMSB and SONBSS, 2012).

For a better energy management, the government of Shanghai is implementing the 12th Five-Year Plan, which is encouraging clean energy production and CO_2 emissions control. Therefore, the investigation of the influence of urban temperature on energy consumption will benefit energy conservation.

In the first part of this study the relationship between temperature and electricity consumption are investigated. Based on this relationship, the base temperatures for cooling and heating demand are derived. In the following sections, relationships between the energy consumption and two climatic indices, namely cooling degree-days (CDD) and heating degree-days (HDD), are used to investigate the correlation with energy consumption in hot and cold months, respectively. With CDD, the climate influence on the cooling energy consumption is assessed and with HDD the heating requirement is estimated. Finally, by applying the future projection of temperature data, the trend in CDD and HDD for 2011–2050 are predicted.

2 Data and methods

Shanghai municipality, with an area of around 6,340 km^2 and a population of over 23.8 million, is located in the center of the eastern coastline of China. Since the 1980s, Shanghai has experienced a rapid urbanization. Until 2012, the built-up area has covered 1,563 km^2.

2.1 *Data*

In this study, the daily and monthly mean temperature data for 1981–2010 were obtained from the Shanghai Climate Center. The Xujiahui observatory has the longest instrument records in China since 1873. Since 1950, another ten meteorological observation stations have been established in urban and rural Shanghai (Fig. 1). With the rapid urbanization, some rural stations are now located in the urban area, such as Xujiahui, Minhang and Baoshan stations. This network provides daily, hourly and even more detailed meteorological observations. Table 1 shows the station's start year, the correlation coefficient of annual mean temperature at each station with that of Xujiahui station, as well as the standard deviation during 1981–2010. The spatial consistency of temperature is analyzed by calculating the correlation coefficient between Xujiahui's annual mean temperature and the other stations. All correlation coefficients in Table 1 are statistical significant at 0.01, which means that all stations change consistently with each other. Stations in the central city have a larger variance than those in the suburbs, reflecting the typical urbanized characteristics of the air temperature in Shanghai.

A high-resolution temperature projection (25 km) was derived by using a regional climate model (RegCM3), which was driven by a global model (CCSR/NIES/FRCGCMIROC3.2_hires) under the A1B scenario. The projection data cover the period of 2011–2050.

Table 1 Standard deviation and correlation coefficients of annual mean temperature between Xujiahui and other stations

Element	Xujiahui	Minhang	Baoshan	Jiading	Chongming	Nanhui	Pudong	Jinshan	Qingpu	Songjiang	Fengxian
Start year	1873	1959	1959	1959	1959	1956	1960	1959	1959	1959	1954
Correlation coefficient	1	0.98	0.99	0.99	0.97	0.97	0.98	0.97	0.99	0.98	0.95
Standard deviation	0.87	0.97	0.81	0.83	0.70	0.65	0.83	0.69	0.76	0.89	0.56